



U.S. Climate Change Policy: An Overview

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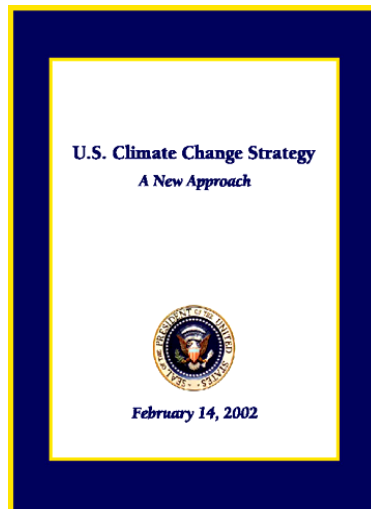
Sixth Annual Conference on Carbon Capture & Sequestration

U.S. Approach



I reaffirm America's commitment to the United Nations Framework Convention and its central goal, to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous human interference with the climate.

President George W. Bush
February 14, 2002

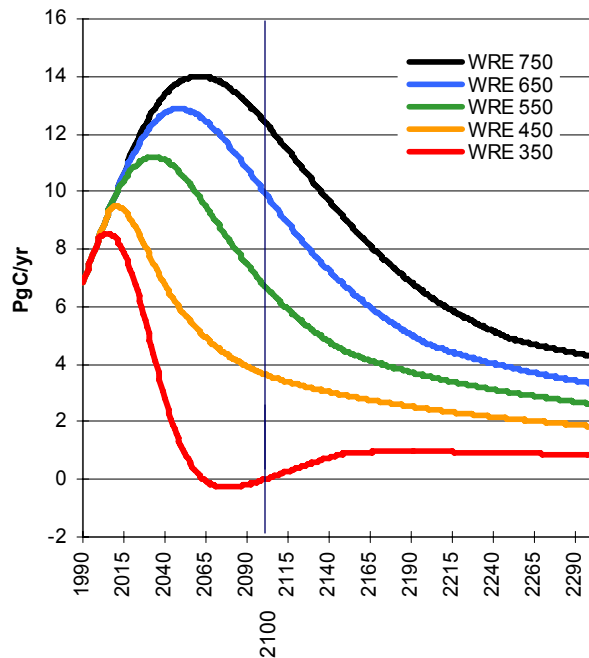


- U.S. approach to climate change harnesses the power of markets and technological innovation, maintains economic growth, and encourages global participation.
- Reaffirms U.S. commitment to goal of UNFCCC.
- Places climate change in a broader context that includes enhancing energy security, encouraging economic growth, and reducing air pollution.
- Four basic elements:
 - ❖ near-term policies & measures, including tax incentives;
 - ❖ improved climate science;
 - ❖ advanced technologies; and
 - ❖ international collaboration.

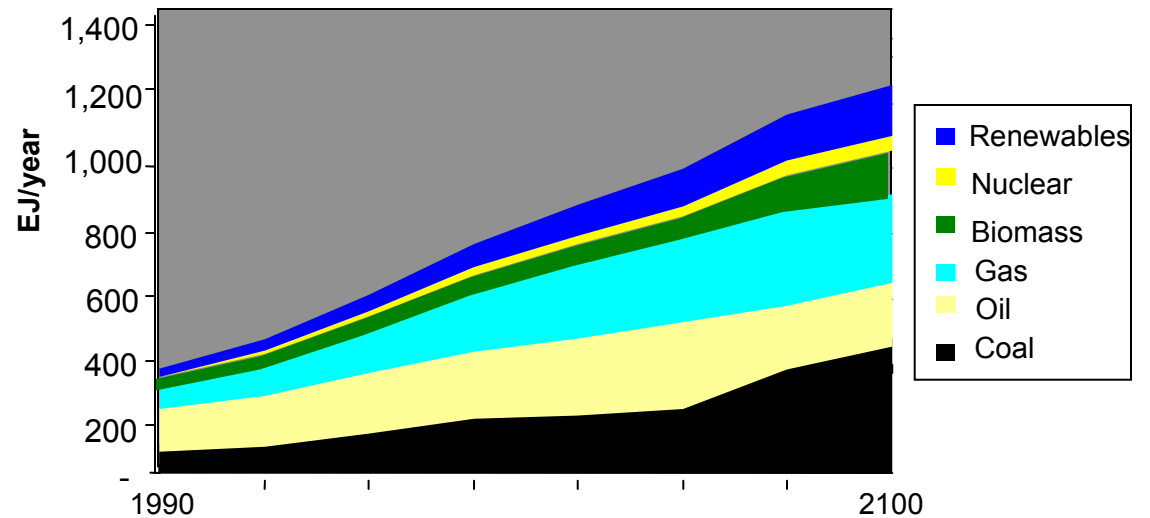
Climate Change Technology: Meeting the Long-Term Challenge

To provide the energy for continued economic growth and development while reducing greenhouse gas emissions, we will have to develop cost-effective technologies that transform the way we produce and use energy.

GHG Stabilization Curves



**Projected World Primary Energy Demand, 1990-2100:
A Reference Case Example**

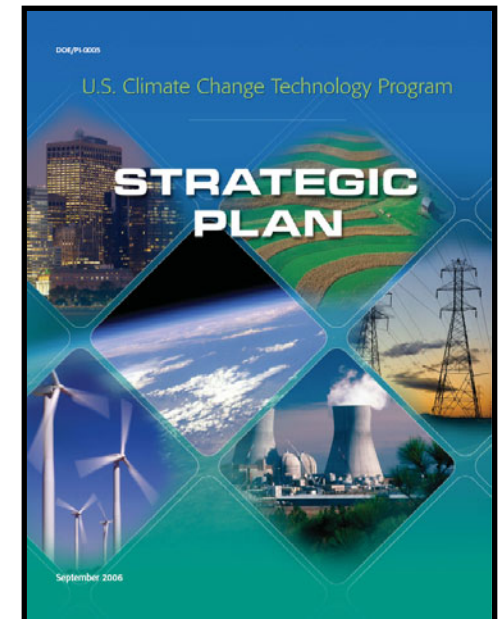


How Big is a Gigaton? Using Today's Technology, These Actions Can Cut Emissions by 1 GtC/Year

Today's Technology	Actions that Provide 1 Gigaton / Year of Mitigation
Coal-Fired Power Plants	Build 1,000 "zero-emission" 500-MW coal-fired power plants (in lieu of coal-fired plants without CO ₂ capture and storage)
Geologic Sequestration	Install 3,700 sequestration sites like Norway's Sleipner project (0.27 MtC/year)
Nuclear	Build 500 new nuclear power plants, each 1 GW in size (in lieu of new coal-fired power plants without CO ₂ capture and storage)
Efficiency	Deploy 1 billion new cars at 40 miles per gallon (mpg) instead of 20 mpg
Wind Energy	Install capacity to produce 50 times the current global wind generation (in lieu of coal-fired power plants without CO ₂ capture and storage)
Solar Photovoltaics	Install capacity to produce 1,000 times the current global solar PV generation (in lieu of coal-fired power plants without CO ₂ capture and storage)
Biomass fuels from plantations	Convert a barren area about 15 times the size of Iowa's farmland (about 30 million acres) to biomass crop production
CO ₂ Storage in New Forest.	Convert a barren area about 30 times the size of Iowa's farmland to new forest

CCTP: Seeking Better and Less Costly Solutions

- Formed in 2002 to coordinate and prioritize Federal climate change-related technology RDD&D:
 - ✓ ≈\$3 billion/year;
 - ✓ 10 R&D agencies participate.
- CCTP authorized in *EPAct2005*.
- CCTP *Strategic Plan* released September 20, 2006.
- Long-term, visionary role for technology—unprecedented 100-year planning horizon and global perspective to meet UNFCCC goal.
- Identifies approaches and a series of next steps to implement the *Plan*.



www.climateotechnology.gov

Value of *Strategic Plan*

- Gives substance to President's technology approach to climate change.
- Complements DOE *Strategic Plan* Goal 1.2, Environmental Impacts of Energy.
- Provides strategic direction and framework for setting R&D investment priorities.
- Argues for better links between basic research and applied R&D.
- Establishes U.S. leadership internationally—*Plan* is unique and a model for others.
- Demonstrates that cost-effective technology options deployed globally can significantly reduce mitigation costs.

CCTP Strategic Goals

- CCTP has:
 - Four emissions-related strategic goals:
 1. Reduce emissions from energy end use & infrastructure;
 2. Reduce emissions from energy supply;
 3. Capture & sequester CO₂; and
 4. Reduce emissions from non-CO₂ gases.
 - And two cross-cutting and supporting strategic goals:
 5. Improve capabilities to measure & monitor GHGs; and
 6. Bolster basic science.
- *Plan* breaks each emission-related strategic goal into four parts:
 1. Potential role for technology;
 2. Technology strategy;
 3. Current portfolio; and
 4. Future research directions.

Roadmap for Climate Change Technology Development

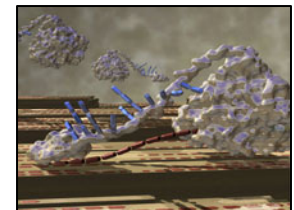
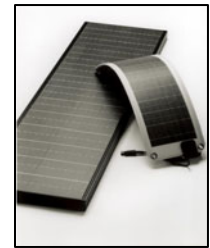
	NEAR-TERM	MID-TERM	LONG-TERM
GOAL #1 Energy End-Use & Infrastructure	<ul style="list-style-type: none"> Hybrid & Plug-In Hybrid Electric Vehicles Engineered Urban Designs High-Performance Integrated Homes High Efficiency Appliances High Efficiency Boilers & Combustion Systems High-Temperature Superconductivity Demonstrations 	<ul style="list-style-type: none"> Fuel Cell Vehicles and H₂ Fuels Low Emission Aircraft Solid-State Lighting Ultra-Efficient HVACR "Smart" Buildings Transformational Technologies for Energy-Intensive Industries Energy Storage for Load Leveling 	<ul style="list-style-type: none"> Widespread Use of Engineered Urban Designs & Regional Planning Energy Managed Communities Integration of Industrial Heat, Power, Process, and Techniques Superconducting Transmission and Equipment
GOAL #2 Energy Supply	<ul style="list-style-type: none"> IGCC Commercialization Stationary H₂ Fuel Cells Cost-Competitive Solar PV Demonstrations of Cellulosic Ethanol Distributed Electric Generation Advanced Fission Reactor and Fuel Cycle Technology 	<ul style="list-style-type: none"> FutureGen Scale-Up H₂ Co-Production from Coal/Biomass Low Wind Speed Turbines Advanced Biorefineries Community-Scale Solar Gen IV Nuclear Plants Fusion Pilot Plant Demonstration 	<ul style="list-style-type: none"> Zero-Emission Fossil Energy H₂ & Electric Economy Widespread Renewable Energy Bio-Inspired Energy & Fuels Widespread Nuclear Power Fusion Power Plants
GOAL #3 Capture, Storage & Sequestration	<ul style="list-style-type: none"> CSLF & CSRP Post Combustion Capture Oxy-Fuel Combustion Enhanced Hydrocarbon Recovery Geologic Reservoir Characterization Soils Conservation Dilution of Direct Injected CO₂ 	<ul style="list-style-type: none"> Geologic Storage Proven Safe CO₂ Transport Infrastructure Soils Uptake & Land Use Ocean CO₂ Biological Impacts Addressed 	<ul style="list-style-type: none"> Track Record of Successful CO₂ Storage Experience Large-Scale Sequestration Carbon & CO₂ Based Products & Materials Safe Long-Term Ocean Storage
GOAL #4 Other Gases	<ul style="list-style-type: none"> Methane to Markets Precision Agriculture Advanced Refrigeration Technologies PM Control Technologies for Vehicles 	<ul style="list-style-type: none"> Advanced Landfill Gas Utilization Soil Microbial Processes Substitutes for SF₆ Catalysts That Reduce N₂O to Elemental Nitrogen in Diesel Engines 	<ul style="list-style-type: none"> Integrated Waste Management System with Automated Sorting, Processing & Recycle Zero-Emission Agriculture Solid-State Refrigeration/AC Systems
GOAL #5 Measure & Monitor	<ul style="list-style-type: none"> Low-Cost Sensors and Communications 	<ul style="list-style-type: none"> Large Scale, Secure Data Storage System Direct Measurement to Replace Proxies and Estimators 	<ul style="list-style-type: none"> Fully Operational Integrated MM Systems Architecture (Sensors, Indicators, Data Visualization and Storage, Models)

Technologies Roadmap for Goal #3: CO₂ Capture, Storage, and Sequestration

	NEAR-TERM	MID-TERM	LONG-TERM
Carbon Capture	<ul style="list-style-type: none"> • CSLF and CSR • Post Combustion Capture • Pre-Combustion Technologies • Oxy-Fuel Combustion • Oxygen Separation Technologies 	<ul style="list-style-type: none"> • Capability to Capture Most CO₂ Emissions • Novel Capture Technologies • Low-Cost Oxygen • Biomass Coupled with CCS 	<ul style="list-style-type: none"> • Novel In-Situ CO₂ Conversion • Capture CO₂ Directly from Atmosphere
Geologic	<ul style="list-style-type: none"> • Reservoir Characterization • Safety, Health, and Environmental Risk Assessment • Understand Underground CO₂ Reactions & Microbial Processes • Enhanced Hydrocarbon Recovery • Enhanced Coal-Bed Methane • Large-Scale Demonstration • CO₂ Transport Network Design 	<ul style="list-style-type: none"> • Geologic Storage Proven Safe • Well Sealing Techniques Demonstrated • Mineralization: Solid Carbonates • Reliable and Accurate Inventory Monitoring • Well-Established CO₂ Transport Infrastructure 	<ul style="list-style-type: none"> • Sufficient CO₂ Storage Capacity • Track Record of Successful CO₂ Storage Experience
Terrestrial	<ul style="list-style-type: none"> • Reforestation • Soils Conservation • Vegetation In Urban Settings 	<ul style="list-style-type: none"> • Soils Uptake & Land Use • Inter-relationship among CO₂, CH₄ & N₂O • Sequestration Decision Support Tools • M&M Tools to Validate Terrestrial Sequestration • Bio-Based & Recycled Products 	<ul style="list-style-type: none"> • Biological Sequestration • Large-Scale Sequestration • Minimal Deforestation • Carbon & CO₂ Based Products & Materials
Ocean	<ul style="list-style-type: none"> • Effective Dilution of Direct Injected CO₂ 	<ul style="list-style-type: none"> • Ocean CO₂ Biological Impacts Addressed • Carbonate Dissolution / Alkalinity Addition 	<ul style="list-style-type: none"> • Safe Long-Term Ocean Storage

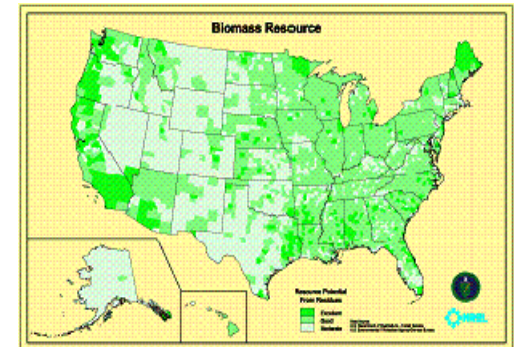
Advanced Energy Initiative

- Goal: Alter the way we power our homes, automobiles & businesses within 20 years.
- President's FY 2008 budget will request a 26% increase in AEI above FY 2007 request, including:
 - ❖ Clean Coal Initiative: \$385MM
 - ❖ Solar America Initiative: \$148MM
 - ❖ Biofuels Initiative: \$179MM
 - ❖ Hydrogen Fuel Initiative: \$309MM
 - ❖ Advanced Battery Research: \$42MM
 - ❖ FutureGen: \$108MM
 - ❖ Nuclear Power 2010: \$114MM
 - ❖ Global Nuclear Energy Partnership: \$405MM
 - ✓ Responds to the challenges of:
 - Global terrorism – threat of nuclear proliferation;
 - Anticipated 50% growth in energy demand by 2025; and
 - Nuclear waste.



“Twenty in Ten”

- In the President’s 2007 State of the Union Address, he announced the “Twenty in Ten” plan to reduce U.S. gasoline usage by 20 percent in 10 years.
- America will reach President’s goal in 2017 by:
 - ❖ increasing the required renewable and alternative fuel content of gasoline; and
 - ❖ reforming CAFE fuel economy standards for cars and extending the current rule for light trucks.
- The plan will help:
 - ❖ increase the Nation’s energy security; and
 - ❖ address climate change concerns by significantly reducing and potentially stopping the growth in GHG emissions from cars & light trucks, potentially avoiding up to 170MMTCO₂e in 2017.
- The President also directed the Federal Government to reduce oil consumption in fleet vehicles, increase use of renewables/alternative fuels and power, and reduce GHG emissions.

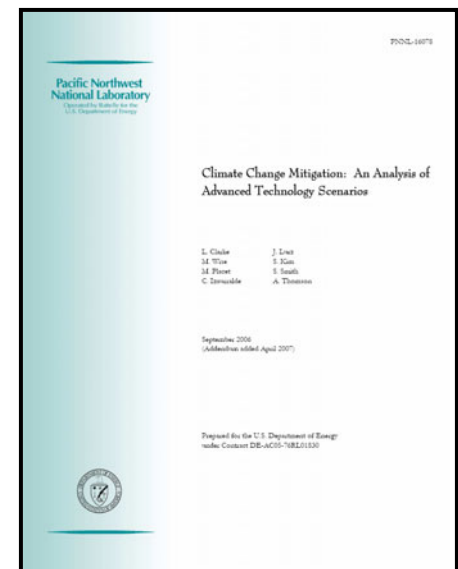


It's in our vital interest to diversify America's energy supply—the way forward is through technology. We must continue changing the way America generates electric power, by even greater use of clean coal technology, solar and wind energy, and clean, safe nuclear power. We need to press on with battery research for plug-in and hybrid vehicles, and expand the use of clean diesel vehicles and biodiesel fuel. We must continue investing in new methods of producing ethanol, using everything from wood chips to grasses, to agricultural wastes.

President George W. Bush
2007 State of the Union Address

Scenario Analysis

- Plan looks at potential of technologies through scenario analysis.
- Scenarios look at different technology futures under a range of uncertainties and carbon constraints.
- Plan sets broad technology development goals in terms of:
 - ❖ Potential quantity of GHG reductions by strategic goal;
 - ❖ Timing of GHG emissions reductions by strategic goal.
- Quantifies benefits of advanced technologies.
- PNNL report available at:
http://www.globalchange.umd.edu/data/publications/CCTP_Final_Report_041007.pdf



Technology Scenarios Explore the Future

Technology Scenario #1: “Closing the Loop on Carbon”

Successful development of carbon capture and storage technologies for use in electricity, as well as in applications such as hydrogen and cement production.

Technology Scenario #2: “A New Energy Backbone”

Additional technological improvement and cost reduction for carbon-free energy sources, such as wind power, solar energy systems, and nuclear power.

Technology Scenario #3: “Beyond the Standard Suite”

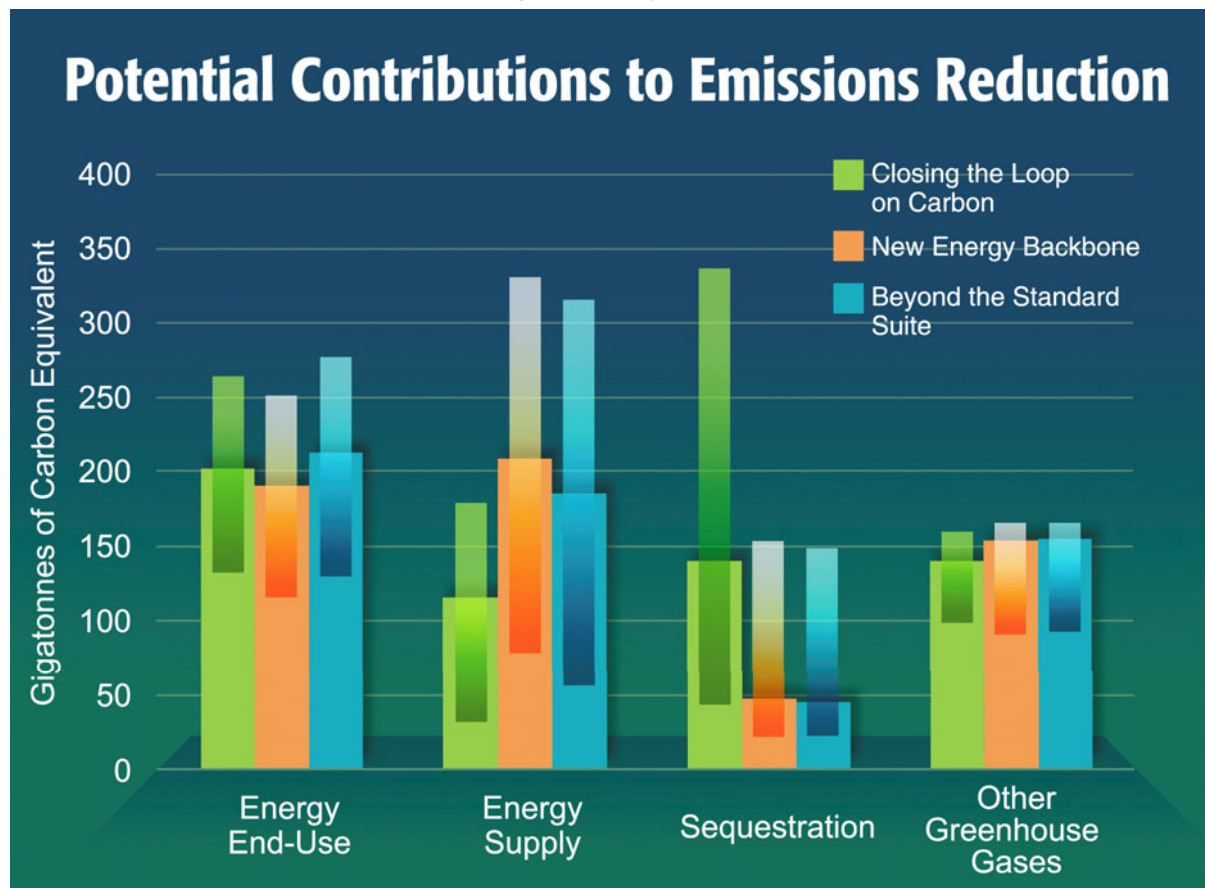
Major advances in fusion energy and/or novel energy applications for solar energy and biotechnology such that they can provide zero-carbon energy at competitive costs in the second half of this century.

Common Characteristics Across Scenarios:

- ✓ *Additional gains in energy efficiency beyond the reference case occur;*
- ✓ *Additional technologies for managing non-CO₂ GHGs become available;*
- ✓ *Terrestrial carbon sequestration increases;*
- ✓ *The full potential of conventional oil and gas is realized; and*
- ✓ *Hydrogen production technology advances.*

Integrated Results

Potential ranges of greenhouse gas emissions reductions to 2100 by category of activity for three technology scenarios characterized by viable carbon sequestration (Closing the Loop on Carbon); dramatically expanded nuclear and renewable energy (New Energy Backbone); and novel and advanced technologies (Beyond the Standard Suite)



Source: Clarke, L., M. Wise, M. Placet, C. Izaurralde, J. Lurz, S. Kim, S. Smith, and A. Thomson. 2006. Climate Change Mitigation: An Analysis of Advanced Technology Scenarios. Richland, WA: Pacific Northwest National Laboratory.

100-Year GHG Mitigations (GtC) by CCTP Goal

CCTP Strategic Goal	Very High Constraint	High Constraint	Medium Constraint	Low Constraint
Goal #1: Reduce Emissions from Energy End Use and Infrastructure	250 - 270	190 - 210	150 - 170	110 - 140
Goal #2: Reduce Emissions from Energy Supply	180 - 330	110 - 210	80 - 140	30 - 80
Goal #3: Capture and Sequester Carbon Dioxide	150 - 330	50 - 140	30 - 70	20 - 40
Goal #4: Reduce Emissions of Non-CO ₂ GHGs	160 - 170	140 - 150	120 - 130	90 - 100

Estimated cumulative GHG emissions mitigation (GtC) from accelerated adoption of advanced technologies over the 21st century, by strategic goal, across a range of hypothesized GHG emissions constraints.

Source: Clarke, L., M. Wise, M. Placet, C. Izaurralde, J. Lurz, S. Kim, S. Smith, and A. Thomson. 2006. Climate Change Mitigation: An Analysis of Advanced Technology Scenarios. Richland, WA: Pacific Northwest National Laboratory.

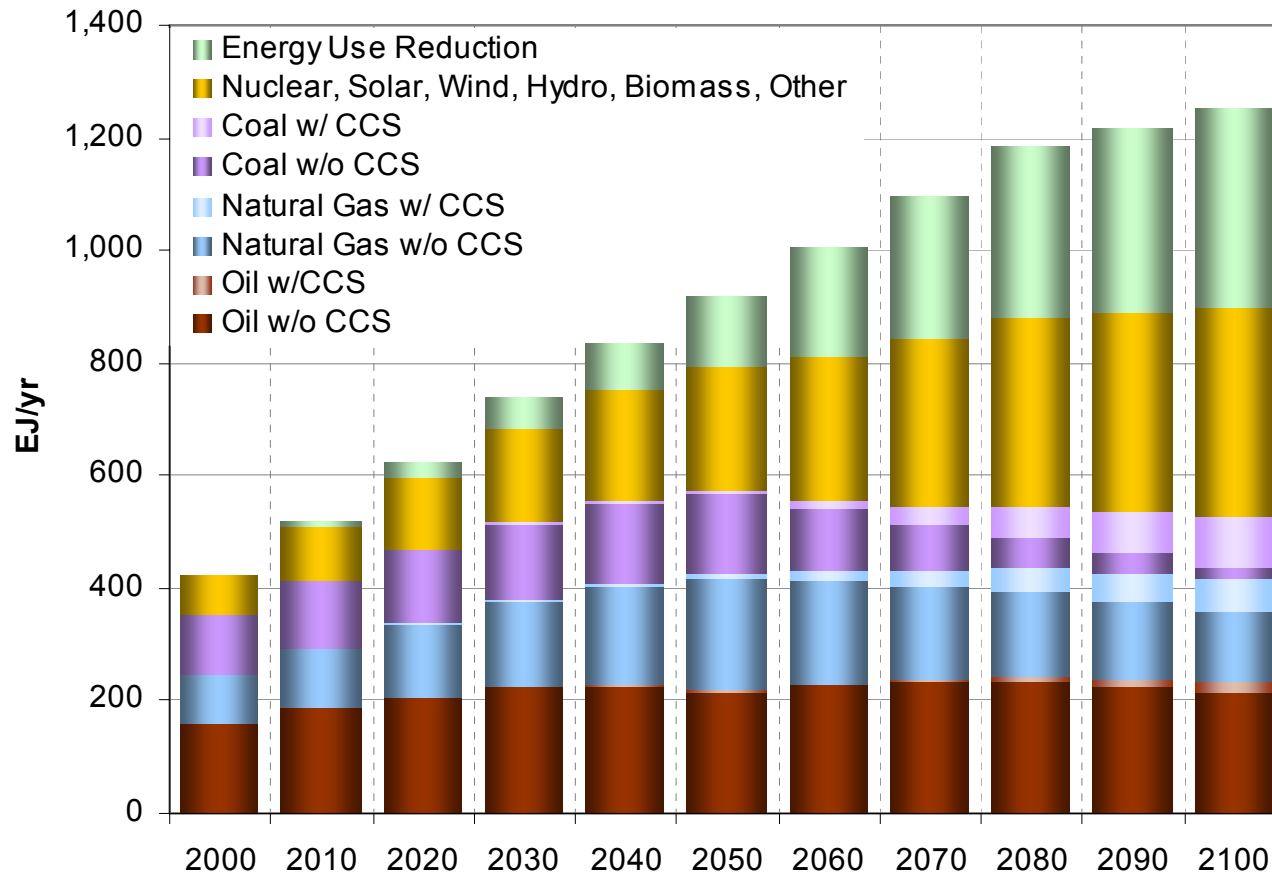
When is the First GtC/yr of Mitigation Due?

CCTP Strategic Goal	Very High Constraint	High Constraint	Medium Constraint	Low Constraint
Goal #1: Reduce Emissions from Energy End Use and Infrastructure	2010 - 2020	2030 - 2040	2030 - 2050	2040 - 2060
Goal #2: Reduce Emissions from Energy Supply	2020 - 2040	2040 - 2060	2050 - 2070	2060 – 2100
Goal #3: Capture and Sequester Carbon Dioxide	2020 - 2050	2040 or Later	2060 or Later	Beyond 2100
Goal #4: Reduce Emissions of Non-CO ₂ GHGs	2020 - 2030	2050 - 2060	2050 - 2060	2070 - 2080

Estimated timing of advanced technology market penetrations, as indicated by the first GtC-eq./year of incremental emissions mitigation, by strategic goal, across a range of hypothesized GHG emissions constraints.

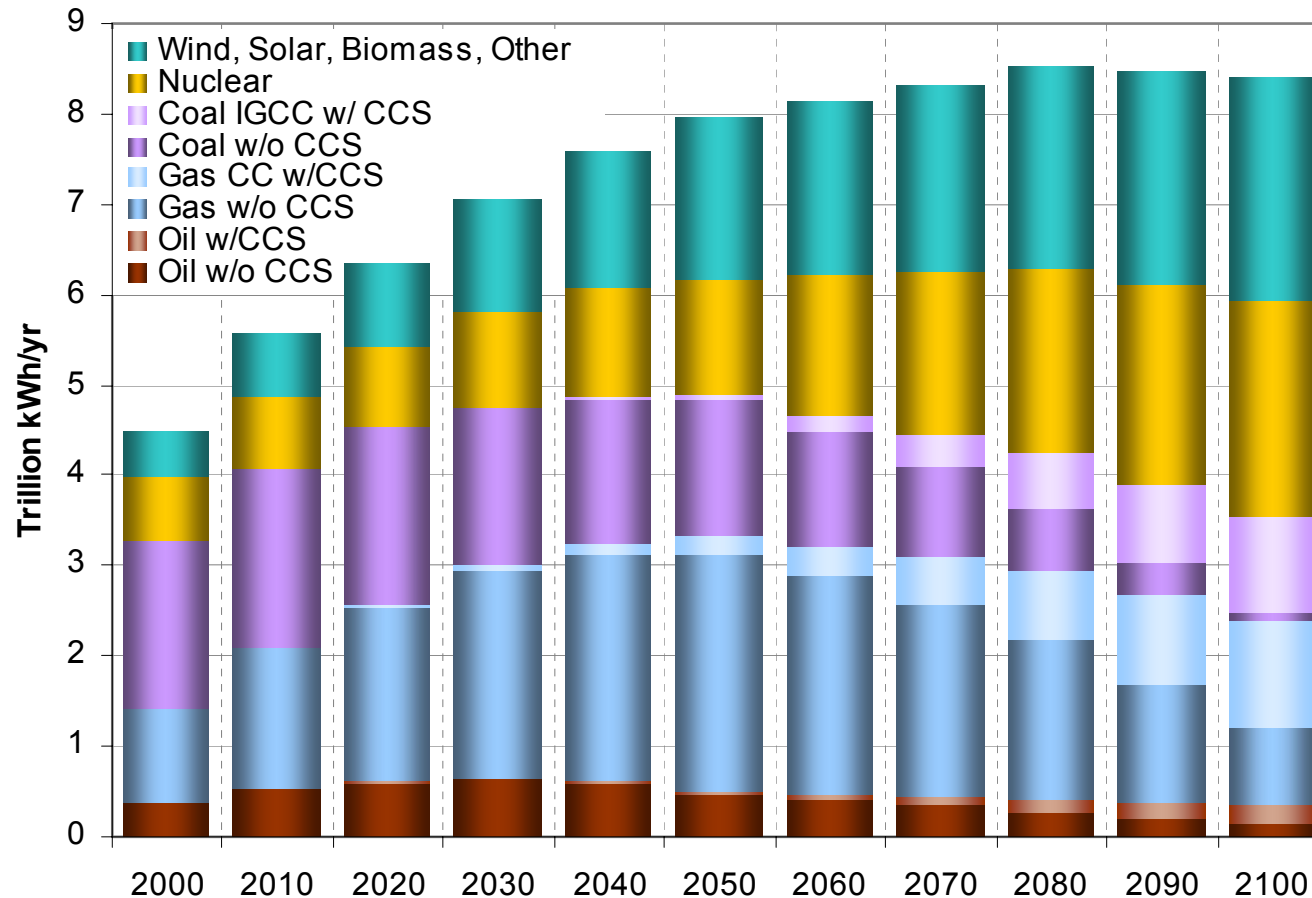
Source:: Clarke, L., M. Wise, M. Placet, C. Izaurralde, J. Lurz, S. Kim, S. Smith, and A. Thomson. 2006. Climate Change Mitigation: An Analysis of Advanced Technology Scenarios. Richland, WA: Pacific Northwest National Laboratory.

Global Primary Energy Consumption: (High Emission Constraint - CLC)



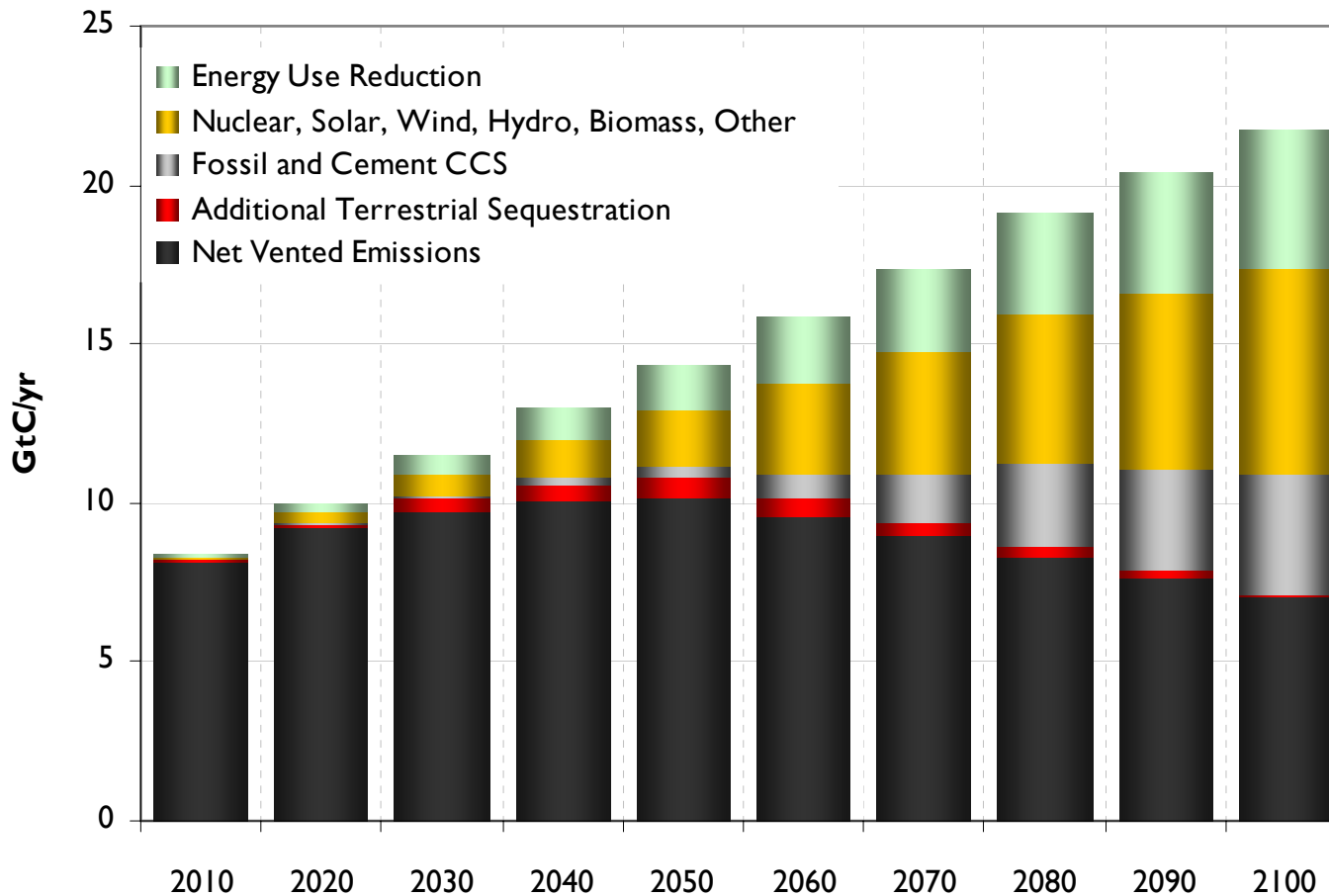
Global Primary Energy Consumption: Closing the Loop on Carbon, 550 ppmv

U.S. Electricity Consumption: (High Emission Constraint - CLC)



United States Electricity Consumption: Closing the Loop on Carbon, 550 ppmv

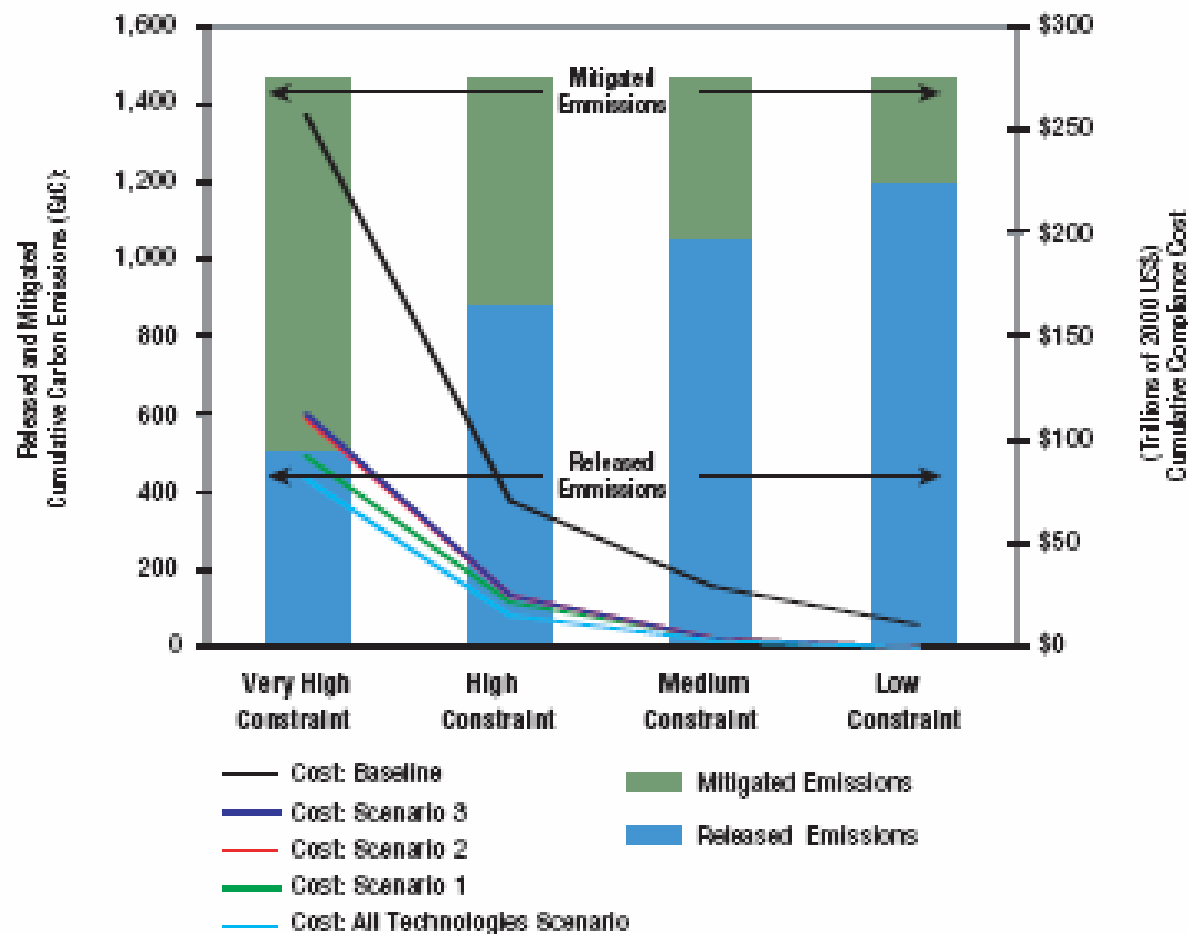
Global Carbon Emissions Reductions: (High Emission Constraint - CLC)



Global Carbon Emissions Reductions: Closing the Loop on Carbon, 550 ppmv

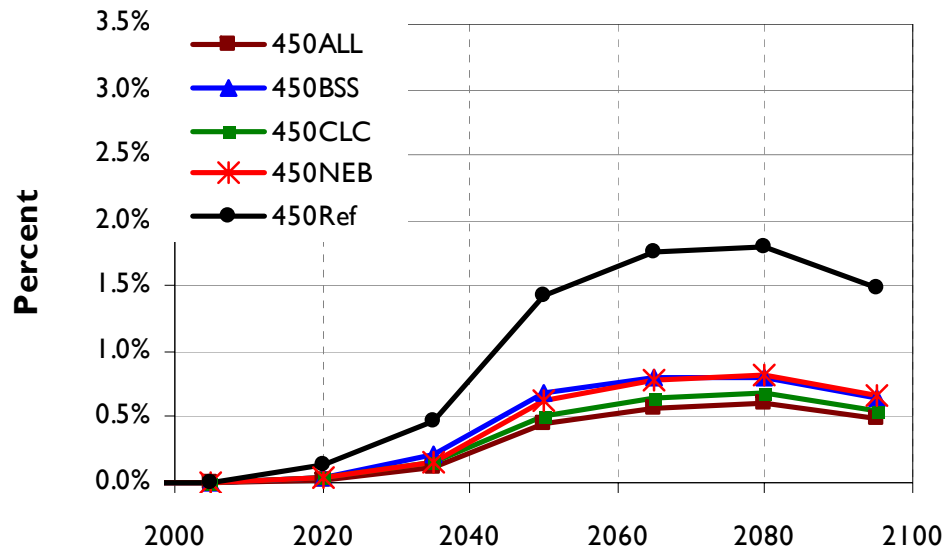
Potential Cost Reductions to 2100

Comparative analysis of estimated cumulative costs over the 21st century of GHG mitigation, with and without advanced technology, across a range of hypothesized GHG emissions constraints.



GDP Losses in CCTP scenarios

United States



The World

